

ELECTRONIC FUNDAMENTALS

SERVICE PRACTICES 8

HOW TO UNDERSTAND METER READINGS

- 8-1. Meter Indications
- 8-2. Meter Sensitivity
- 8-3. A-C Voltmeter Sensitivity
and Circuit Loading
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meter



RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

HOME STUDY SCHOOL

350 West 4th Street, New York 14, N. Y.

Service Practices 8

INTRODUCTION

Every profession or trade uses measuring instruments. One of the most important measuring instruments used by radio and television servicemen is the multimeter. It is important to be able to use your multimeter correctly and to be sure that it is always in correct operating condition.

The first part of this Service Practices booklet explains how to judge the readings you get on your multimeter. If you do not know how to judge multimeter readings, you will not be able to use your multimeter to help you find trouble in radio and TV sets. It is possible that you may mistake a correct voltage, resistance, or current for an incorrect one just because you are not using your meter properly.

The second part of this booklet discusses how to locate and correct any defects in the multimeter itself caused by incorrect wiring, defective parts, or incorrect use.

PART ONE

8-1 METER INDICATIONS

When you make a measurement with a multimeter, you must know what reading to expect if the circuit is operating properly. If you do not get the reading you expect, and you are using your meter properly, you know that there is trouble in the circuit you are measuring. But if you are not using your meter properly, you will not get a useful reading from the circuit under test — even a circuit that is operating correctly may seem to be defective.

Parallax. It is possible for you to get a correct reading on your multimeter and still not know that it is correct just because you are looking at the meter scale and pointer

from the wrong angle. This is due to *parallax*, which may be defined as the seeming difference in the position of an object when seen from different positions.

Let's try a little experiment to see how parallax affects meter readings. You will need an ordinary table knife. Hold the knife over the 0-100-volt meter scale shown in Fig. 8-1a, with the blade straight up and down and with the lower edge about two

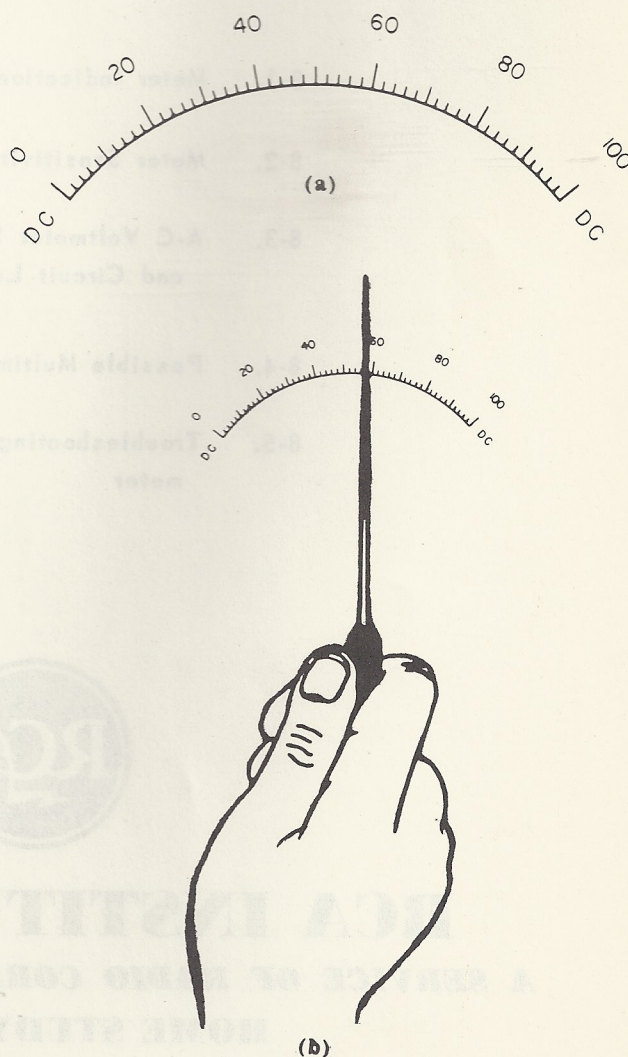


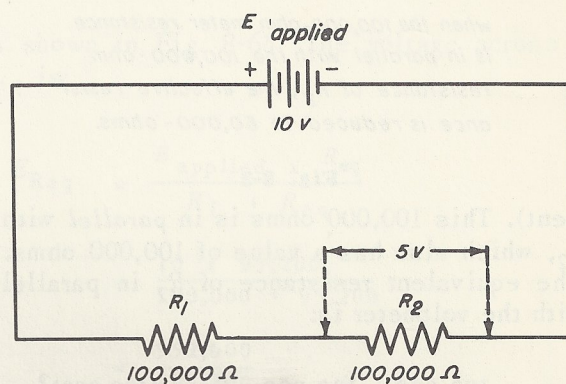
Fig. 8

inches above the scale, as shown in Fig. 8-1b. With your eyes about four inches above and directly over the upper edge of the blade, look at the meter scale. Note the reading. With your head moved a little to the right of the blade, take another reading. Then move your head a little to the left of the blade and take one more reading.

If you hold the knife directly over the center of the scale, the first reading should be about halfway between 40 and 60 — giving a reading of 50 volts. With your head moved to the right of the blade, the reading falls somewhere between 40 and 50 volts, while with your head to the left of the blade, the reading is between 50 and 60 volts. The only correct reading is the one taken directly over the blade. The difference between this and either of the other readings is due to parallax. The only correct way to read a meter is to place yourself directly in front of it, with the calibration, the needle, and the center point between your eyes all in the same straight line.

Voltage Indications. As you know, your d-c voltmeter can be used on either the 5 VDC, 25 VDC, 100 VDC, or 500 VDC ranges. When the test prods are connected to a circuit in a radio receiver to measure d-c voltage, the potential being measured always appears across a circuit containing resistance. The value of the resistance in a circuit may be very low, very high, or somewhere in between. Sometimes the circuit across which the d-c voltage is being measured is in series with other circuits that may have low, medium, or high values of resistance. Figure 8-2 shows 10 volts d.c. applied to two series resistors, R_1 and R_2 . From your study of Theory Lesson 8, you know that, in a series circuit, the current flowing is the same in any part, and that the sum of the voltage drops is equal to the applied voltage. Because this is so, we can also say that *the voltage drop across any part of a series circuit is in proportion to the resistance of the part divided by the total resistance of the circuit.* Therefore, the voltage across R_2 equals the applied voltage multiplied by R_2 divided by R_1 plus R_2 , or

$$\begin{aligned} E_{R2} &= \frac{E_{\text{applied}} \times R_2}{R_1 + R_2} \\ &= \frac{10 \times 100,000}{100,000 + 100,000} \\ &= \frac{1,000,000}{200,000} \\ &= 5 \text{ volts} \end{aligned}$$

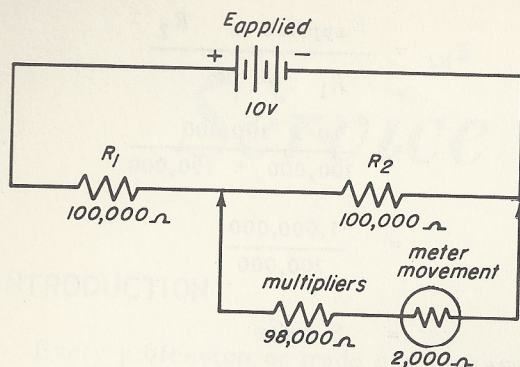


The voltage across R_2 is 5 volts

Fig. 8-2

Therefore, you expect that the reading on the multimeter will be 5 volts. Yet, if you measure the voltage across R_2 , using the 5 VDC scale, the meter will show a reading of only 3.33 volts. What causes the d-c voltmeter to indicate 3.33 volts across R_2 when, according to our rule, you should expect 5 volts to appear across it if a potential of 5 volts *does* exist across R_2 without the voltmeter connected? Apparently the voltmeter affects the circuit. With the voltmeter connected, the voltage across R_2 is decreased. How does the voltmeter cause this reduced voltage reading? To find an answer, let's look at the circuit when the meter is connected across R_2 .

Looking at Fig. 8-3, you can see that when the test prods are connected to R_2 , the voltmeter itself becomes a part of the circuit under test. In the 5 VDC position, the voltmeter resistance equals 100,000 ohms (the 98 k-ohm multiplier in series with the 2,000-ohm resistance of the meter move-



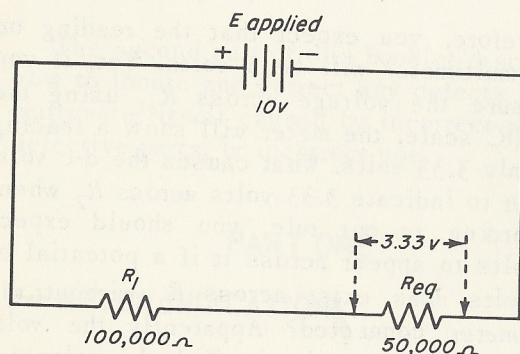
when the 100,000-ohm meter resistance is in parallel with the 100,000-ohm resistance of R_2 , the effective resistance is reduced to 50,000-ohms.

Fig. 8-3

ment). This 100,000 ohms is in parallel with R_2 , which also has a value of 100,000 ohms. The equivalent resistance of R_2 in parallel with the voltmeter is:

$$\frac{100,000 \times 100,000}{100,000 + 100,000} = \frac{(100,000)^2}{200,000}$$

$$= 50,000 \text{ ohms}$$



R_{eq} (the equivalent of R_2 in parallel with the 5-v d-c voltmeter) has a voltage of 3.33 volts across it.

Fig. 8-4

Figure 8-4 shows that connecting the voltmeter across the circuit makes it seem that the resistance of R_2 is reduced from 100 k- to 50 k-ohms. With the voltmeter connected, R_2 is now identified as R_{eq} . The 10-volt potential applied to the circuit does not divide equally between both resistors as before but now causes a smaller voltage to

appear across R_{eq} , since it has been reduced in value from 100 k- to 50 k-ohms by the shunting effect of the voltmeter circuit. The voltage across R_2 in parallel with the voltmeter (R_{eq}) as read by the meter is:

$$E_{Req} = \frac{E_{\text{applied}} \times R_{eq}}{R_1 + R_{eq}}$$

$$= \frac{10 \times 50,000}{100,000 + 50,000}$$

$$= \frac{500,000}{150,000}$$

$$= 3.33 \text{ volts}$$

where

E_{Req} is the potential across the parallel combination of R_2 and the voltmeter.

E_{applied} is 10 volts

R_1 is the 100,000-ohm resistor.

If you measure the voltage across R_2 with the RANGE selector switch in the 25 VDC position instead of the 5 VDC position, the circuit will be as shown in Fig. 8-5a. We can see that the total voltmeter resistance equals 500,000 ohms. The equivalent resistance of R_2 is parallel with the meter is:

$$R_{eq} = \frac{500,000 \times 100,000}{500,000 + 100,000}$$

$$= \frac{5 \times 10^{10}}{6 \times 10^5}$$

$$= 83,300 \text{ ohms (approx)}$$

as shown in Fig. 8-5b. The potential across R_{eq} is:

$$E_{Req} = \frac{E_{\text{applied}} \times R_{eq}}{R_1 + R_{eq}}$$

$$= \frac{10 \times 83,300}{183,300}$$

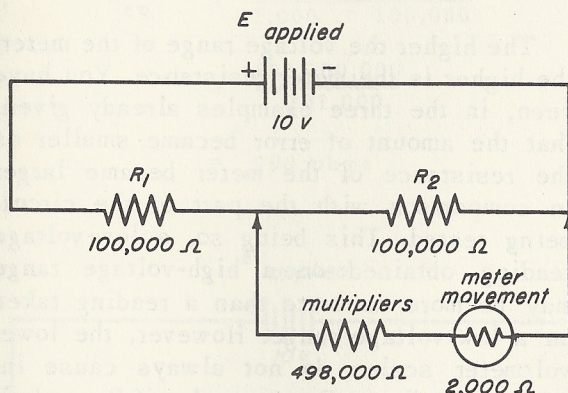
$$= 4.54 \text{ volts}$$

where:

E_{Req} is the potential across the parallel combination of R_2 and the voltmeter.

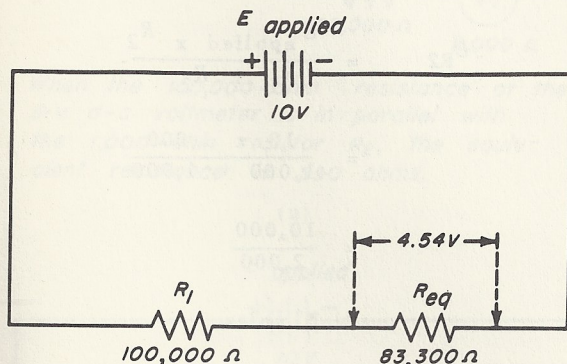
$E_{applied}$ is 10 volts

R_1 is the 100 k-ohm resistor



When the 500,000-ohm voltmeter resistance is in parallel with the 100,000-ohm resistance of R_2 , the equivalent resistance is 83,300 ohms.

(a)



R_{eq} (R_2 in parallel with 25 v d-c voltmeter resistance) has a voltage of 4.54 volts across it.

(b)

Fig. 8-5

Suppose that you were to use the voltmeter with the RANGE selector switch in the 100 VDC position to indicate the voltage across R_2 . Figure 8-6a shows that the resistance of the voltmeter circuit equals 2,000,000 ohms. When the test prods are connected to R_2 , the shunting effect of the voltmeter causes the effective resistance of R_2 to be reduced from 100,000 ohms to:

$$\begin{aligned} R_{eq} &= \frac{100,000 \times 2,000,000}{100,000 + 2,000,000} \\ &= \frac{2 \times 10^{11}}{2.1 \times 10^6} \\ &= \frac{2 \times 10^5}{2.1} \\ &= 0.952 \times 10^5 \\ &= 95,200 \text{ ohms,} \end{aligned}$$

as shown in Fig. 8-6b. The voltage across R_{eq} is:

$$\begin{aligned} E_{Req} &= \frac{E_{applied} \times R_{eq}}{R_1 + R_{eq}} \\ &= \frac{10 \times 95,200}{100,000 + 95,200} \\ &= \frac{952,000}{195,200} \\ &= 4.88 \text{ volts} \end{aligned}$$

where

E_{Req} is the voltage across the parallel combination of R_2 and the voltmeter.

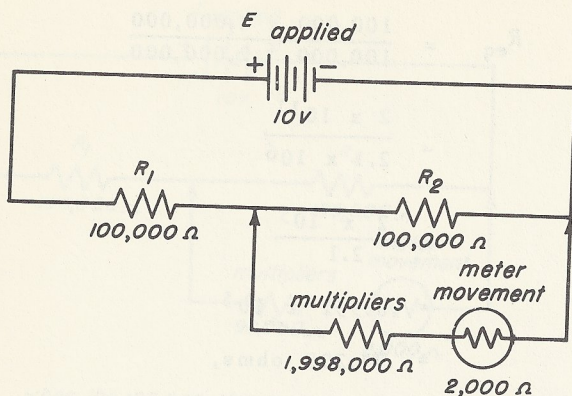
$E_{applied}$ is 10 volts

R_1 is the 100,000-ohm resistor.

Circuit Loading. If you compare the voltmeter readings obtained across R_2 when the RANGE selector knob was in the three different multiplier positions, you will learn that:

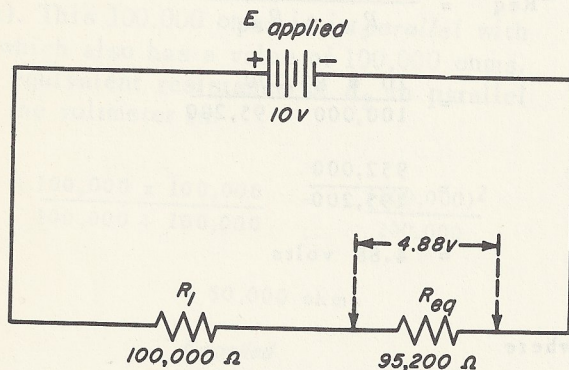
1. A voltmeter acts in parallel with the circuit being tested, and, therefore, lowers the resistance value of the circuit that it is used to test.

2. The lower voltmeter multiplier circuits have less resistance than the higher ranges. This causes the lower ranges, when used, to change and lower the resistance of the circuit being tested to a greater degree than when the higher ranges of the meter are used to make measurement of voltage.



When the 2,000,000-ohm voltmeter resistance is parallel with 100,000-ohm resistance of R_2 , the equivalent resistance is 95,200 ohms.

(a)



R_{eq} (R_2 in parallel with 100-v d-c voltmeter resistance) has a voltage of 4.88 volts across it.

(b)

Fig. 8-6

When a voltmeter changes the resistance value of the circuit to which it is connected, we say that the meter loads the circuit. Circuit loading takes place whenever a meter such as yours is used to measure voltage. In many cases, the loading is so slight that it makes little or no difference in the voltage reading. However, under certain conditions, the loading is so great that the error in the voltage reading is very large. Voltmeters give accurate readings when:

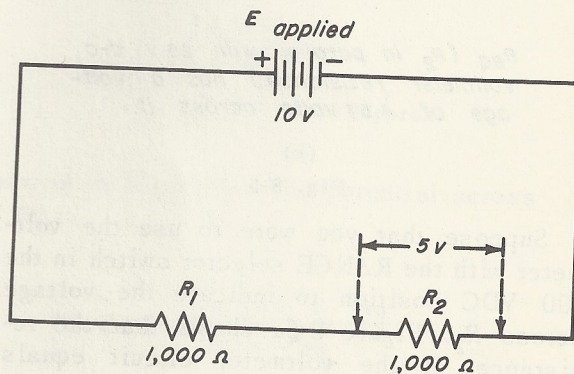
1. The resistance of the voltmeter is much greater than the resistance being tested. (A rule-of-thumb is that when the meter resistance is ten or more times the resistance of the part of the

circuit being tested, the error is so small that it may be ignored.)

2. The equivalent resistance of the meter in parallel with the part of the circuit being tested is much greater than the sum of all other resistance values in series with the circuit being measured.

The higher the voltage range of the meter, the higher is the meter resistance. You have seen, in the three examples already given, that the amount of error became smaller as the resistance of the meter became larger in comparison with the part of the circuit being tested. This being so, a low-voltage reading obtained on a high-voltage range may be more accurate than a reading taken on a low-voltage range. However, the lower voltmeter scales do not always cause incorrect readings. For example, if R_1 and R_2 each had a resistance value of 1,000 ohms instead of 100,000 ohms, as shown in Fig. 8-7, the voltage across R_2 without the voltmeter connected would be:

$$\begin{aligned}
 E_{R2} &= \frac{E_{\text{applied}} \times R_2}{R_1 + R_2} \\
 &= \frac{10 \times 1,000}{1,000 + 1,000} \\
 &= \frac{10,000}{2,000} \\
 &= 5 \text{ volts}
 \end{aligned}$$

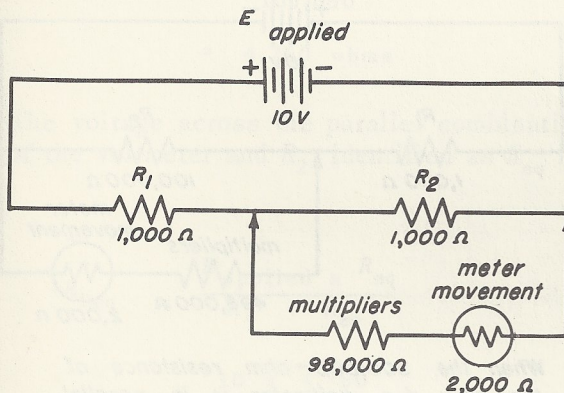


The voltage across R_2 is 5 volts.

Fig. 8-7

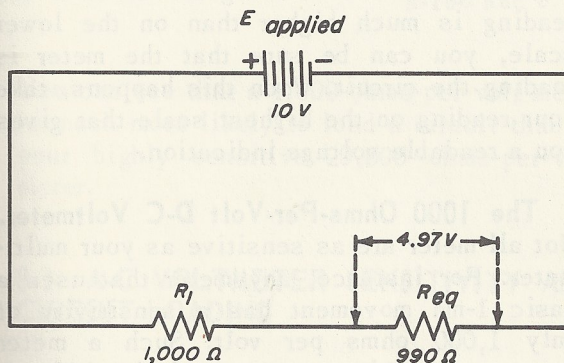
When the voltmeter is connected to R_2 with the RANGE selector knob in the 5 VDC position, the parallel-resistance combination of the voltmeter resistance (100,000 ohms) in shunt with R_2 (1,000 ohms) shown in Fig. 8-8a is:

$$\begin{aligned} R_{eq} &= \frac{1,000 \times 100,000}{1,000 + 100,000} \\ &= \frac{100,000,000}{101,000} \\ &= 990 \text{ ohms} \end{aligned}$$



When the 100,000-ohm resistance of the 5-v d-c voltmeter is in parallel with the 1,000-ohm resistor R_2 , the equivalent resistance is 990 ohms.

(a)



R_{eq} (R_2 in parallel with 5-v d-c voltmeter) has a voltage of 4.97 v across it.

(b)

Fig. 8-8

The required voltage across R_{eq} , shown in Fig. 8-8b, is:

$$\begin{aligned} E_{Req} &= \frac{E_{\text{applied}} \times R_{eq}}{R_1 + R_{eq}} \\ &= \frac{10 \times 990}{1,000 + 990} \\ &= \frac{9,900}{1,990} \\ &= 4.97 \text{ volts} \end{aligned}$$

As you can see the meter causes practically no error when its resistance is very much higher than the resistance of the part of the circuit being tested.

When the combination of the meter and the part being tested has much greater resistance than the rest of the series circuit, meter loading will affect the voltage reading very little. Figure 8-9a shows two resistors in series connected across ten volts. R_1 measures 1,000 ohms and R_2 is 100,000 ohms. The voltage across R_2 is:

$$\begin{aligned} E_{R2} &= \frac{E_{\text{applied}} \times R_2}{R_1 + R_2} \\ &= \frac{10 \times 100,000}{1,000 + 100,000} \\ &= \frac{1,000,000}{101,000} \\ &= 9.90 \text{ volts} \end{aligned}$$

When the 25 VDC position is connected across R_2 (Fig. 8-9b), R_2 is in parallel with 500,000 ohms meter resistance. The equivalent circuit is:

$$\begin{aligned} R_{eq} &= \frac{100,000 \times 500,000}{100,000 + 500,000} \\ &= \frac{50 \times 10^9}{6 \times 10^5} \\ &= \frac{50 \times 10^4}{6} \\ &= 8.33 \times 10^4 \\ &= 83,300 \text{ ohms} \end{aligned}$$

then:

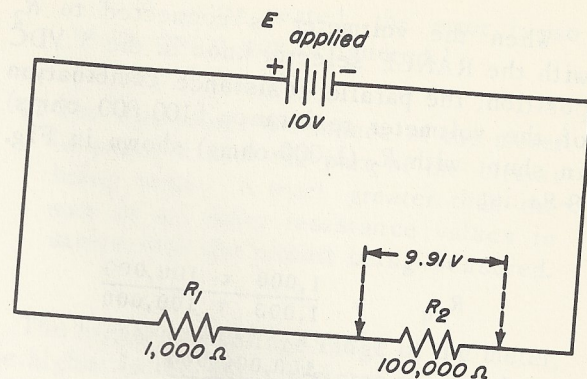
$$\begin{aligned}
 E_{Req} &= \frac{E_{\text{applied}} \times R_{eq}}{R_1 + R_{eq}} \\
 &= \frac{10 \times 83,300}{1,000 + 83,300} \\
 &= \frac{8330}{843} \\
 &= 9.88 \text{ volts}
 \end{aligned}$$

As you can see, meter loading has little effect on this voltage reading.

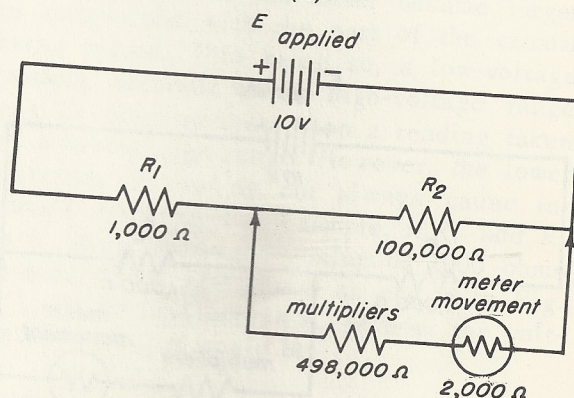
8-2 METER SENSITIVITY

Meters are sometimes rated by the amount of current required to make the needle go to full scale. When so rated, the meter that requires the least amount of current is rated the most sensitive. For example, the basic meter movement used in your multimeter is a very sensitive instrument; it requires only 50 microamperes of current through the moving coil to force the needle to full scale. Another way uses an ohms-per-volt rating, which is used in rating voltmeters. The ohms-per-volt rating is found by dividing the meter resistance by the number of volts indicated when the needle goes to full scale for a particular voltage range. The meter resistance is the sum of the resistance of the basic meter movement and the multiplier resistance for the particular scale. For example, your multimeter has a resistance of 100,000 ohms on the 5 VDC range. The sensitivity is found by dividing 100,000 by 5 (the number of volts indicated by a full-scale deflection of the needle). We find that 20,000 ohms is the answer and that the sensitivity of your meter is 20,000 ohms per volt. You will find that you'll get the same answer no matter which scale you use.

In most cases, when using your voltmeter, you do not have to worry much about circuit loading and inaccurate readings. However, when you are in doubt about the accuracy of a voltage reading, due to what you may suspect to be circuit loading, take



The voltage across R_2 is 9.91 volts.
(a)



When the 500,000-ohm resistance of the 25-v d-c voltmeter is in parallel with the 100,000 ohms of R_2 , the equivalent resistance is 83,300 ohms.
(b)

Fig. 8-9

a reading on the next higher scale. If the reading is much higher than on the lower scale, you can be sure that the meter is loading the circuit. When this happens, take your reading on the highest scale that gives you a readable voltage indication.

The 1000 Ohms-Per-Volt D-C Voltmeter.

Not all meter are as sensitive as your multimeter. For instance, any meter that uses a basic 1-ma movement has a sensitivity of only 1,000 ohms per volt. Such a meter causes a very large amount of circuit loading when making d-c voltage measurements in modern radio, TV, or general electronic equipment. One milliamper (1,000 microamperes) of current is needed to deflect the needle to the full-scale position, while our meter requires only 50 microamperes. Therefore, our meter is $\frac{1000}{50} = 20$ times more sensitive to changes in current. The volt-

meter resistance of a 1000-ohms-per-volt d-c voltmeter is *only 5,000 ohms*, when used in the 5 VDC position. You can see that such a low-resistance voltmeter would cause a very large amount of circuit loading. For example, Fig. 8-10a shows that the voltage drop across R_2 is 5 volts. If a 1,000-ohms-per-volt d-c voltmeter is connected across R_2 with the RANGE selector knob in the 5 VDC position, the combined parallel resistance of the voltmeter and R_2 is:

$$\begin{aligned} R_{eq} &= \frac{5,000 \times 100,000}{5,000 + 100,000} \\ &= \frac{500,000,000}{105,000} \\ &= 4,760 \text{ ohms} \end{aligned}$$

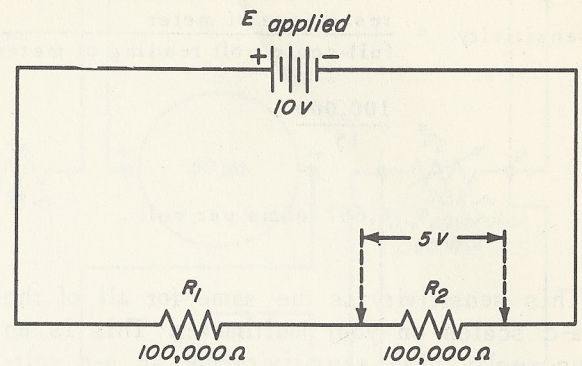
The voltage across the parallel combination of the voltmeter and R_2 , identified as R_{eq} is:

$$\begin{aligned} E_{Req} &= \frac{E_{\text{applied}} \times R_{eq}}{R_1 + R_{eq}} \\ &= \frac{10 \times 4,760}{100,000 + 4,760} \\ &= \frac{47,600}{104,760} \\ &= 0.45 \text{ volts, as shown in Fig. 8-10b and c.} \end{aligned}$$

You can see that a 1,000-ohms-per-volt meter is much more likely to load a circuit than is your highly sensitive 20,000 ohms-per-volt meter.

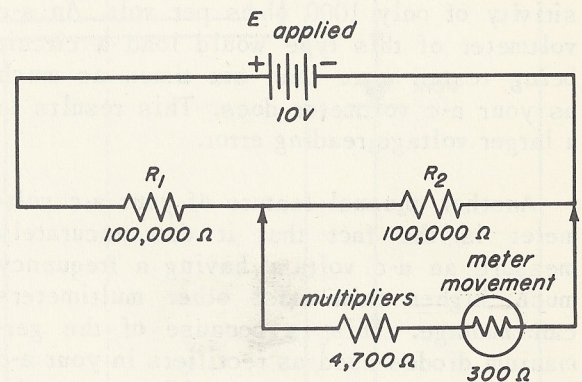
8-3. A-C VOLTMETER SENSITIVITY AND CIRCUIT LOADING

The a-c voltmeter is not used as often as the d-c voltmeter when troubleshooting and repairing radio receivers. However, when it is used, it is important to know what results to expect and under what conditions the meter will load the circuit. Earlier in this lesson, we learned that the sensitivity of a voltmeter in ohms per volt is equal to voltmeter resistance divided by



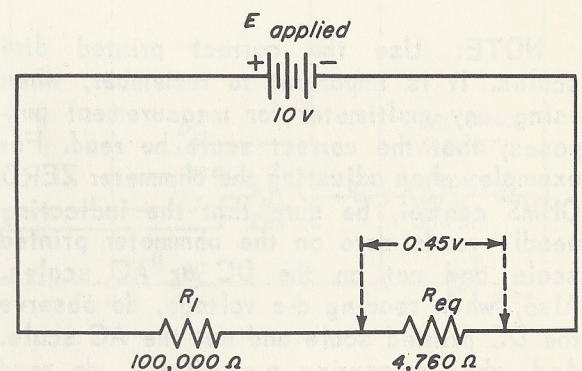
The voltage across R_2 is 5 volts.

(a)



When the 5,000 ohms of the voltmeter is in parallel with the 100,000 ohms of R_2 , the equivalent resistance is 4.760 ohms.

(b)



R_{eq} (R_2 in parallel with the 5VDC range of the 1,000-ohms-per-volt meter) has 0.45 volts across it.

(c)

Fig. 8-10

the full-scale voltage. For the 15-volt scale, our a-c voltmeter resistance is 100,000 ohms. Therefore:

$$\begin{aligned}
 \text{Sensitivity} &= \frac{\text{resistance of meter}}{\text{full-scale volt reading of meter}} \\
 &= \frac{100,000}{15} \\
 &= 6,667 \text{ ohms per volt}
 \end{aligned}$$

This sensitivity is the same for all of the a-c scales on your multimeter. This is an unusually high sensitivity for an a-c voltmeter compared with other a-c voltmeters used in multimeter circuits. Many types of a-c voltmeters on the market have a sensitivity of only 1000 ohms per volt. An a-c voltmeter of this type would load a circuit being tested more than six times as much as your a-c voltmeter does. This results in a larger voltage-reading error.

Another unusual feature of your a-c voltmeter is the fact that it can accurately measure an a-c voltage having a frequency much higher than most other multimeters can manage. This is because of the germanium diodes used as rectifiers in your a-c voltmeter. (Diodes and rectifiers are discussed fully in a Theory Lesson later in this course.) Many a-c voltmeters use copper-oxide rectifiers, which do not measure a-c voltages at higher a-c frequencies as accurately as do germanium diodes.

NOTE: Use the correct printed dial scales. It is important to remember, when using any multimeter for measurement purposes, that the correct scale be read. For example, when adjusting the ohmmeter ZERO OHMS control, be sure that the indicating needle reads zero on the ohmmeter printed scale and not on the DC or AC scales. Also, when reading d-c voltage, do observe the DC printed scale and not the AC scale. And when measuring a-c voltage, do read the AC scale and not the DC voltage scale.

PART TWO

8-4. POSSIBLE MULTIMETER TROUBLES

When you have completed the wiring of your multimeter, you may find that it does

not work properly on one or more ranges. Or, after the multimeter has been in use for some time, you may discover that there is something wrong with it. In either case, it will save you a lot of time and effort if you know how to go about locating the trouble and correcting it. Most of the troubles that may affect your multimeter can be located by carefully following the troubleshooting instructions given in the following pages. Do not try any short cuts. Follow each step in the troubleshooting procedure in the order given and you will protect your meter from accidental damage while you make your tests.

If your meter does not work properly, there are many possible reasons. However, for your multimeter, there are six basic kinds of trouble

1. The meter does not work on any range in any function.
2. The meter does not work on one or more d-c voltmeter ranges.
3. The meter does not work on one or more a-c voltmeter ranges.
4. The meter does not work on one or more ohmmeter ranges.
5. The meter does not work on one or more current ranges.
6. The meter does not work on the output voltage ranges.

While the troubleshooting instructions that follow were written to help you troubleshoot your multimeter, the method and order of tests are basically the same for any multimeter that uses a D'Arsonval moving-coil movement. The system of multipliers and shunts for the voltage and current ranges of any multimeter are very much like those in your multimeter. When you study Theory Lesson 11, you will find that there are several different systems used in wiring ohmmeter circuits. For this reason, it is important to know what ohmmeter circuits are being used in any other multimeter so that you may trace them in troubleshooting.

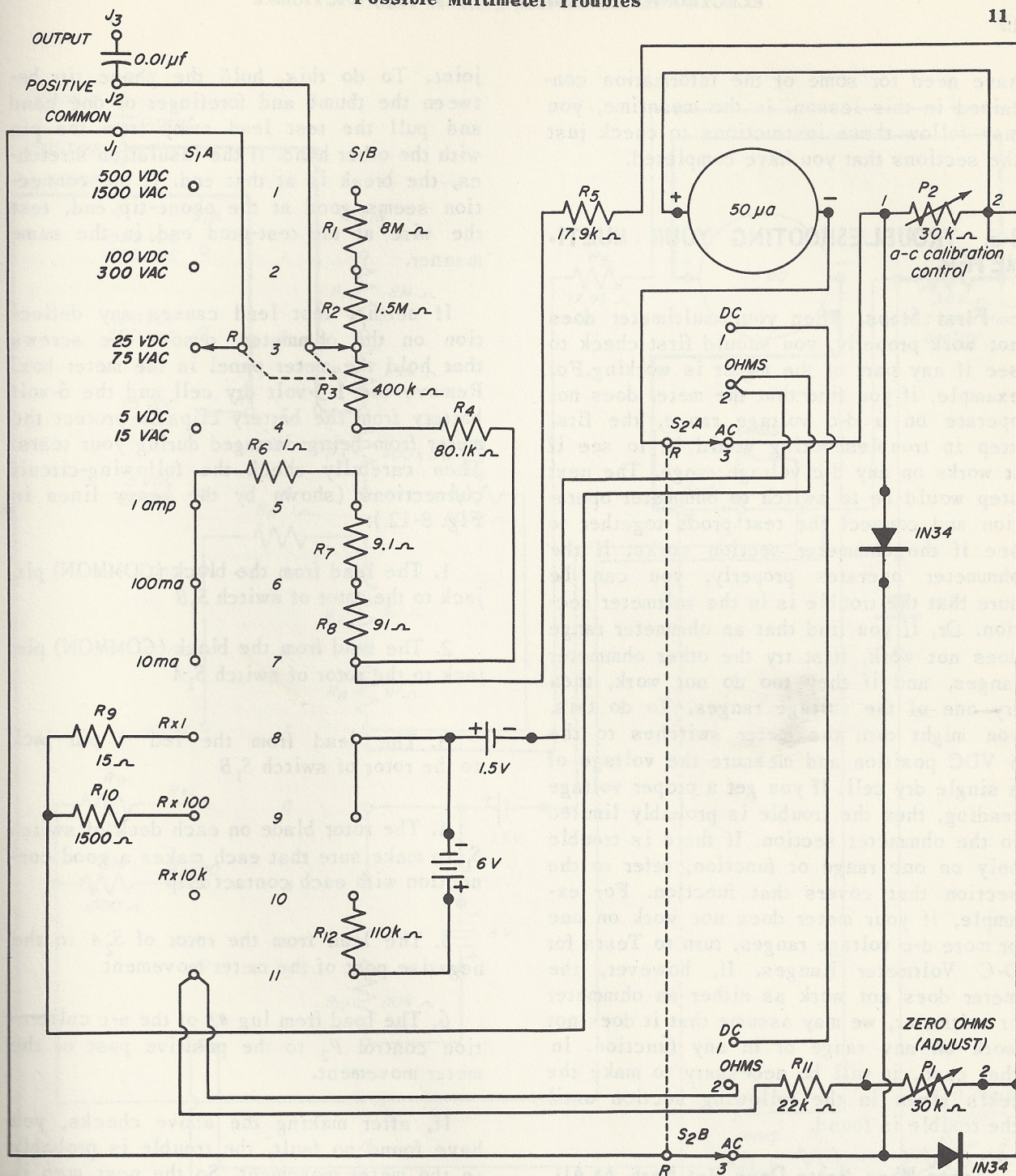


Fig. 8-11

Sometimes a schematic drawing may be obtained from the manufacturer of the multimeter or from one of the organizations that publish schematics and service data for servicemen.

Figure 8-11 shows the complete schematic diagram for your multimeter. At the

time that you receive this booklet, you will not have wired the a-c section. However, as you know, these Service Practices booklets are designed to be kept handy for ready reference when needed, while you are taking the course and even long after you have finished the course. After you have completed wiring the a-c section of your multimeter, you may

have need for some of the information contained in this lesson. In the meantime, you may follow these instructions to check just the sections that you have completed.

8-5. TROUBLESHOOTING YOUR MULTIMETER

First Steps. When your multimeter does not work properly, you should first check to see if any part of the meter is working. For example, if you find that the meter does not operate on a d-c voltage range, the first step in troubleshooting would be to see if it works on any d-c voltage range. The next step would be to switch to ohmmeter operation and connect the test prods together to see if the ohmmeter section works. If the ohmmeter operates properly, you can be sure that the trouble is in the voltmeter section. Or, if you find that an ohmmeter range does not work, first try the other ohmmeter ranges, and if they too do not work, then try one of the voltage ranges. To do this, you might turn the meter switches to the 5 VDC position and measure the voltage of a single dry cell. If you get a proper voltage reading, then the trouble is probably limited to the ohmmeter section. If there is trouble only on one range or function, refer to the section that covers that function. For example, if your meter does not work on one or more d-c voltage ranges, turn to Tests for D-C Voltmeter Ranges. If, however, the meter does not work as either an ohmmeter or voltmeter, we may assume that it does not work on any range or in any function. In that case, it will be necessary to make the tests given in the following section until the trouble is found.

Tests When Meter Does Not Work At All.

First check the test leads. To do this, set the meter up for operation on the R x 1 ohmmeter scale. Then remove the red test lead from the + pin jack. Connect one end of the black test lead to the COMMON pin jack and the other end to the + pin jack. If the ohmmeter works, test the red lead in the same way. If the meter needle deflects for one test lead and not the other, you can be sure that the lead that causes no deflection is defective. Then test each end of the defective test lead for a break or a poor

joint. To do this, hold the phone tip between the thumb and forefinger of one hand and pull the test lead away from the pin with the other hand. If the insulation stretches, the break is at that end. If the connection seems good at the phone-tip end, test the wire at the test-prod end in the same manner.

If neither test lead causes any deflection on the ohmmeter, remove the screws that hold the meter panel in the meter box. Remove the 1.5-volt dry cell and the 6-volt battery from the battery clips to protect the meter from being damaged during your tests. Then carefully check the following-circuit connections (shown by the heavy lines in Fig. 8-12.):

1. The lead from the black (COMMON) pin jack to the rotor of switch S_2B
2. The lead from the black (COMMON) pin jack to the rotor of switch S_1A
3. The lead from the red + pin jack to the rotor of switch S_1B
4. The rotor blade on each deck of switch S_1 to make sure that each makes a good connection with each contact clip
5. The lead from the rotor of S_2A to the negative post of the meter movement
6. The lead from lug #2 of the a-c calibration control P_2 to the positive post of the meter movement.

If, after making the above checks, you have found no fault, the trouble is probably in the meter movement. So the next step is to check the movement. Of course, if either of the spiral springs or the moving coil is burned out because of meter overloading, it will be easy to see because the needle may be badly bent. However, it is possible for a meter movement to open up because of some defect in manufacture or because of rough handling. The meter movement may be checked in this manner:

1. Disconnect all wires from both terminals of the meter.

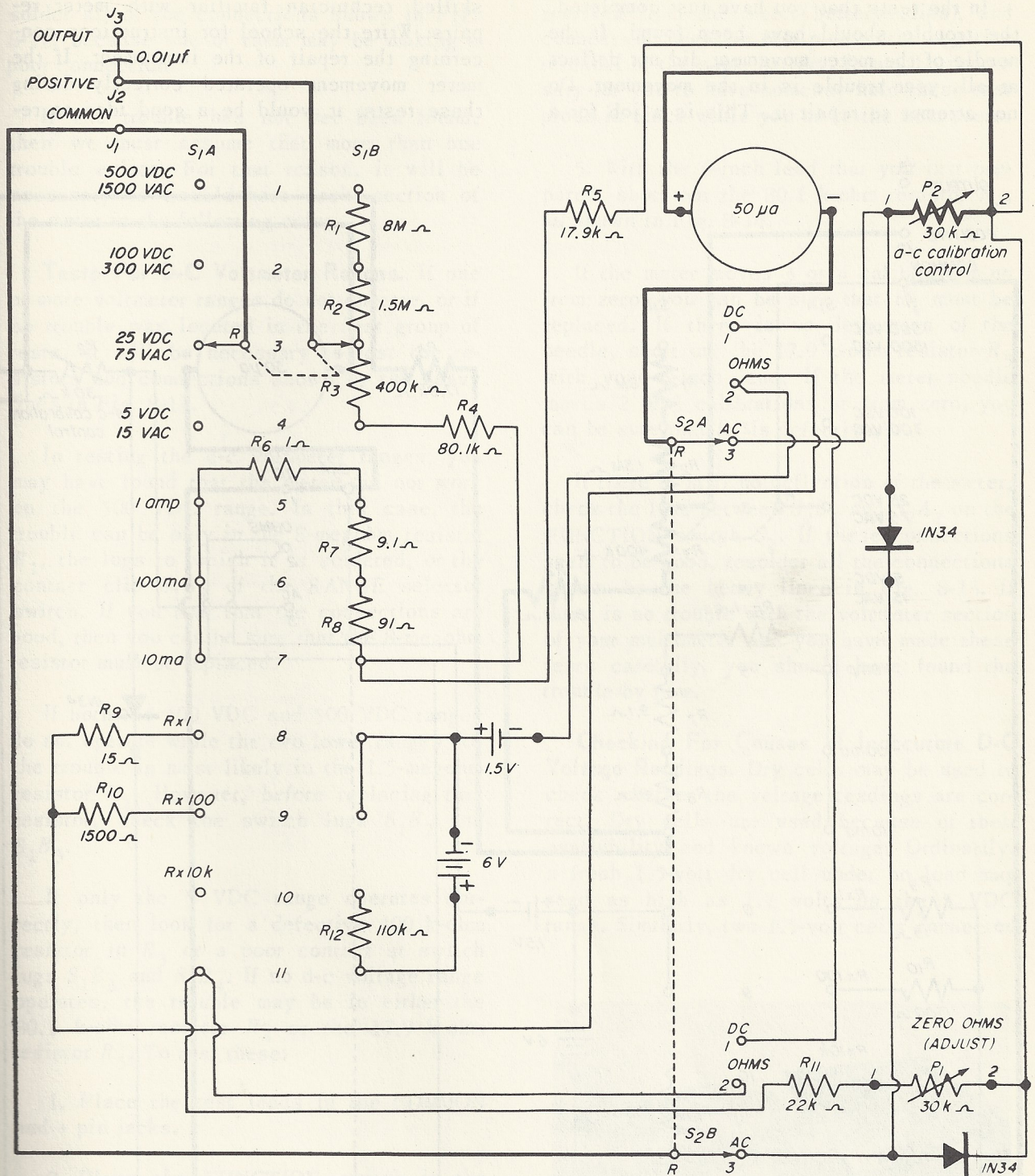


Fig. 8-12

2. Connect the negative terminal of the dry cell to the negative terminal of the meter, making sure that the positive terminal of the cell *does not* touch the positive terminal of the meter.

3. Moisten both forefingers; place one

finger on the positive terminal of the cell and one finger on the positive meter terminal

4. Observe the meter needle; if there is even the slightest movement of the needle, it shows that the meter movement is operating in a normal manner.

In the tests that you have just completed, the trouble should have been found. If the needle of the meter movement did not deflect at all, your trouble is in the movement. Do not attempt to repair it. This is a job for a

skilled technician familiar with meter repairs. Write the school for instructions concerning the repair of the instrument. If the meter movement operated correctly during these tests, it would be a good idea to re-

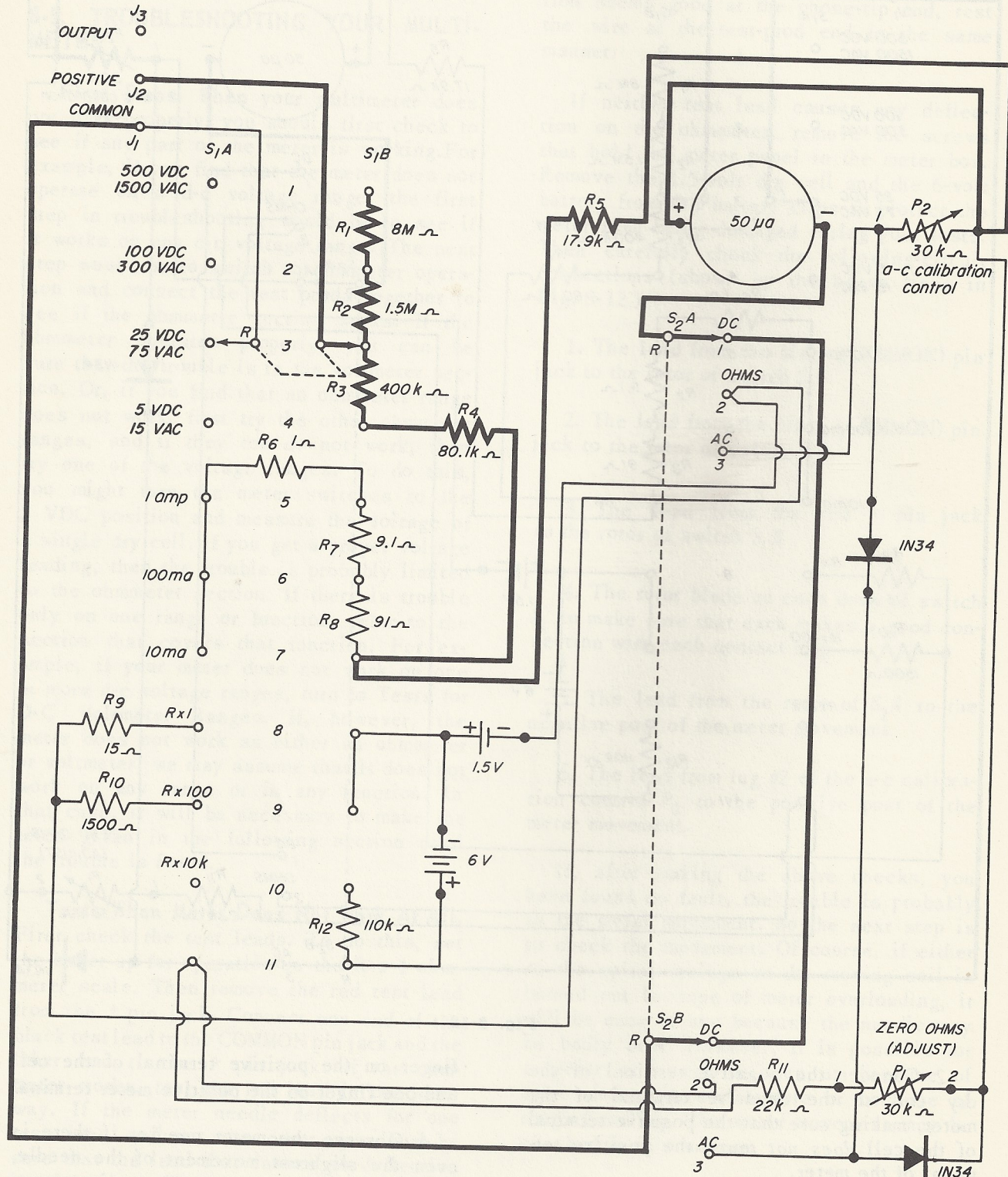


Fig. 8-13

solder all of the connections shown in Fig. 8-12, because one of them may be making a poor connection.

If the trouble has not yet been found, then we must assume that more than one trouble exists. For that reason, it will be necessary to troubleshoot each section of the meter in the following order.

Tests For D-C Voltmeter Ranges. If one or more voltmeter ranges do not operate, or if no trouble was located in the first group of tests, it will be necessary to test the resistors and connections shown by the heavy lines in Fig. 8-13.

In testing the d-c voltmeter ranges, you may have found that the meter did not work on the 500 VDC range. In this case, the trouble can be only in the 8-megohm resistor R_1 , the lugs to which it is soldered, or the contact clip S_1B_1 of the RANGE selector switch. If you find that the connections are good, then you can be sure that the 8-megohm resistor must be replaced.

If both the 100 VDC and 500 VDC ranges do not operate while the two lower ranges do, the trouble is most likely in the 1.5-megohm resistor R_2 . However, before replacing this resistor, check the switch lugs S_1B_2 and S_1B_3 .

If only the 5 VDC range operates correctly, then look for a defective 400 k-ohm resistor in R_3 or a poor contact at switch lugs S_1B_3 and S_1B_4 . If no d-c voltage range operates, the trouble may be in either the 80.1 k-ohm resistor R_4 or the 17.9 k-ohm resistor R_5 . To test these:

1. Place the test leads in the COMMON and + pin jacks.
2. Place the FUNCTION switch in the DC position and the RANGE switch in the 25 VDC position.
3. Remove $\frac{1}{4}$ -inch of insulation from each end of a 6-inch length of solid hook-up wire.
4. Connect the red test prod to the positive terminal of the 6-volt battery (which you

removed from the meter battery clips), and connect the negative test prod to the negative terminal of the same battery. It may be necessary for you to have someone hold these test prods in place while you make the next tests.

5. With the 6-inch lead that you just prepared, short out the 80.1 k-ohm resistor R_4 , as shown in Fig. 8-14.

If the meter moves 3 or 4 calibrations up from zero, you can be sure that R_4 must be replaced. If there is no deflection of the needle, short out the 17.9 k-ohm resistor R_5 with your 6-inch lead. If the meter needle moves 2 or 3 calibrations up from zero, you can be sure that R_5 is defective.

If there is still no deflection of the meter, check the lead between S_2B_1 and S_2A_1 on the FUNCTION switch S_2 . If these connections seem to be good, resolder all the connections shown by the heavy lines in Fig. 8-13. If there is no trouble with the voltmeter section of your multimeter and you have made these tests carefully, you should have found the trouble by now.

Checking For Causes of Inaccurate D-C Voltage Readings. Dry cells may be used to check whether the voltage readings are correct. Dry cells are used because of their availability and known voltage. Ordinarily, a fresh 1.5-volt dry cell under no load may read as high as 1.7 volts on the 5 VDC range. Similarly, two 1.5-volt cells connected

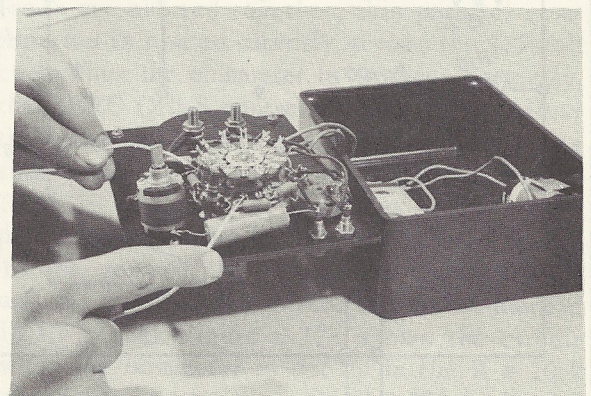


Fig. 8-14

in series may read as high as 3.4 volts. As the dry cells age and under loaded conditions, the voltage of a dry cell may become 1.5 volts and lower. A wrong indication of voltage as read on any or all of the four d-c scales may be a wrong or changed value of resistance. For example, if the 5 VDC-scale readings are accurate, the 80.1 k-ohm and 17.9 k-ohm resistors are normal. If the 25 VDC scale readings are accurate, the 80.1 k-ohm,

17.9 k-ohm, and 400 k-ohm resistors are normal. But if the 100 VDC scale readings are not accurate, the 1.5-megohm resistor should be replaced. If R_1 has changed value or has a value other than the 8-megohms, the accuracy of the 500 VDC scale will be affected. If all d-c voltage ranges read high or low, either the 80.1 k-ohm resistor R_4 or the 17.9 k-ohm resistor R_5 may have changed value or be of the wrong value.

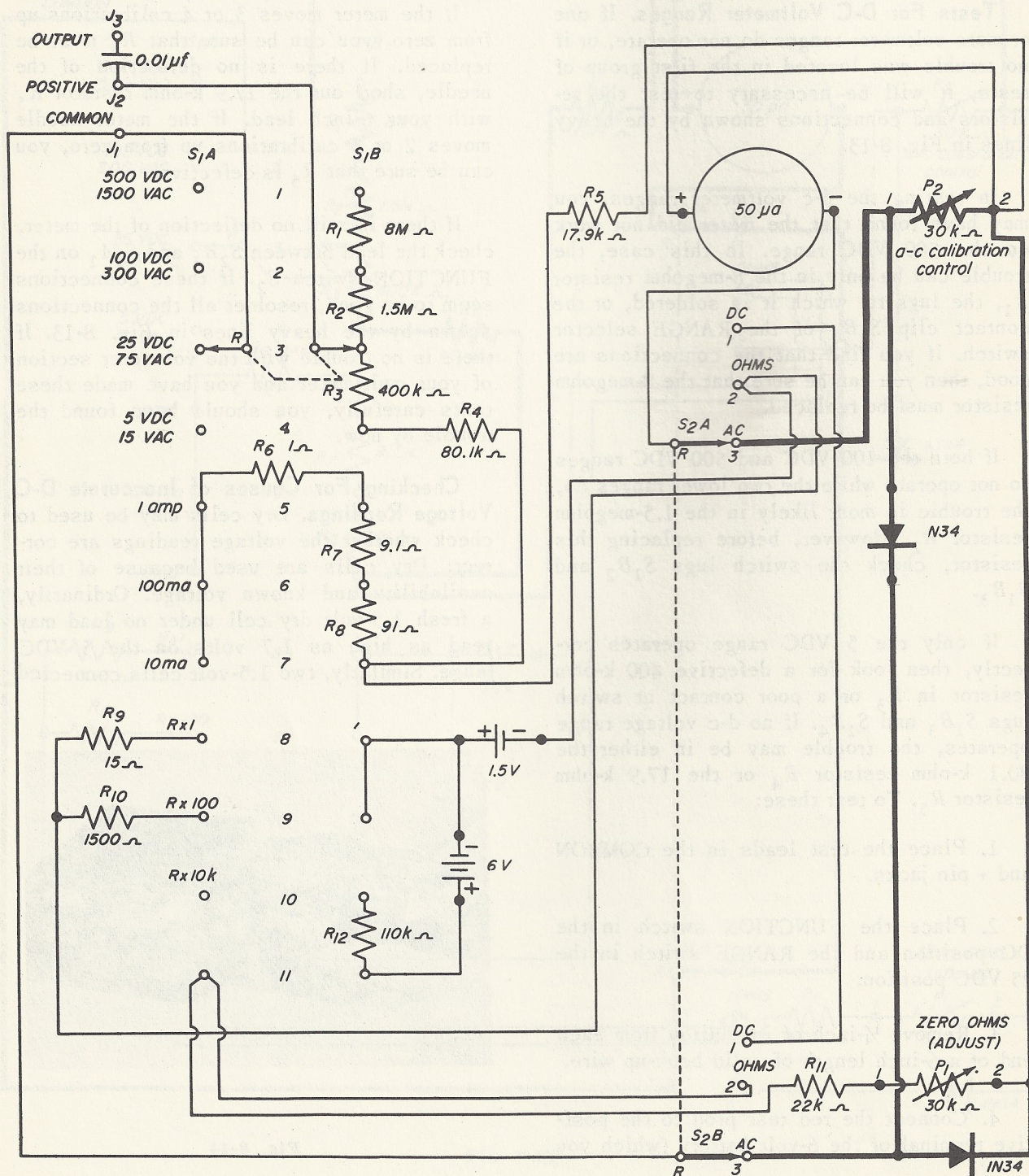


Fig. 8-15

Another cause of inaccurate d-c voltage readings may be loose or poorly soldered connections, especially at resistor and switch-lug connections. A poor solder joint may either cause the voltage reading to be inaccurate or cause the meter needle to waver and sway back and forth. Make sure that all connections are well-soldered.

If the d-c voltage readings are low on all ranges, it is possible that the 50- μ a meter may be faulty. If you have reason to believe that this is so, please write the school, submitting voltage readings on the 5 VDC range of one, two, and three 1.5-volt dry cells connected in series along with any other pertinent information. You will be advised by the school as to what should be done.

Tests For A-C Voltmeter Ranges. These tests can be made only when you have already wired the a-c section of your multimeter. If this section has not been wired, go on to the next group of tests (Tests for Ohmmeter Ranges).

In these tests, it is assumed that the multimeter works on the d-c voltage ranges but does not work on the a-c voltage ranges. To test the a-c voltage ranges, it is necessary to test that part of the multimeter circuit shown by the heavy lines in Fig. 8-15.

1. Examine the connection between the FUNCTION switch lug S_2A_3 and terminal 1 on potentiometer P_2 .

2. Examine the connection between the FUNCTION switch lug S_2B_3 and the common connection between the two 1N34 crystals.

3. Examine each of the other connections to the two 1N34 crystal-diode rectifiers.

4. Examine the connection between the centertap terminal 2 of the a-c calibration control P_2 and one of the 1N34 crystals.

If all of these connections are correct, the trouble may be in one or both of the 1N34 crystals. Test them as follows:

1. Set up the multimeter for service on the

R x 100 scale. (This means that it will be necessary to replace the 1.5-volt dry cell in its clip in the meter case.)

2. Remove one of the crystals from its clip. Connect the black test lead to the cathode end of the crystal and the red test lead to the anode end. The resistance may be as high as 400 ohms. This is called measuring the forward resistance.

3. Set the multimeter for service on the R x 10 k scale. Reverse the leads to the crystal and measure the resistance again. The resistance reading should be at least 100,000 ohms. This is called measuring the backward resistance.

4. Test the other 1N34 crystal in the same manner. If you have made these and other tests carefully, any trouble in the a-c voltage section of your multimeter should have been located.

Tests For Ohmmeter Ranges. The heavy lines in Fig. 8-16 shows the parts and connections that are in the meter circuit when it is used as an ohmmeter. These consist of four fixed resistors (R_9 , R_{10} , R_{11} , and R_{12}), the ZERO OHMS control (P_1), a 6-volt battery, and a 1.5-volt dry cell. The parts actually in the ohmmeter circuit when the RANGE selector switch is in the R x 1 position are shown in Fig. 8-17a. The 22 k-ohm resistor R_{11} , the ZERO OHMS control P_1 , and the meter movement are in series with each other. This series circuit is in parallel with the 15-ohm resistor R_9 . When the test leads are shorted together, this parallel combination is placed directly across the 1.5-volt cell. When the ohmmeter is working correctly, the ZERO OHMS control P_1 is used to adjust the ohmmeter to zero ohms. The only changes that take place in this circuit when the RANGE selector is turned to the R x 100 position, as shown in Fig. 8-17b, are that the 15-ohm resistor R_9 is cut out of the circuit and the 1,500-ohm resistor R_{10} is connected in its place. Figure 8-17c shows the circuit when the ohmmeter is set up in the R x 10 k position. As you can see, the 110 k-ohm resistor R_{12} and the 6-volt battery are placed in series with the 1.5-volt cell, and there is no parallel resistor in use.

Let us assume that the meter does not work on any ohmmeter range. The most probable fault will be that the 1.5-volt cell is defective or that it is not making good contact with the terminals of its battery clip. To test it, remove the cell from the clip and test it on the 5 VDC range. If it tests 1.3

volts or higher, replace it in its battery clip and make sure that it is making good contact with the clip terminals. Set up the meter for operation on the R x 1 ohmmeter range. If the ohmmeter still does not operate, the trouble is an open circuit. It will be necessary to check the following connections:

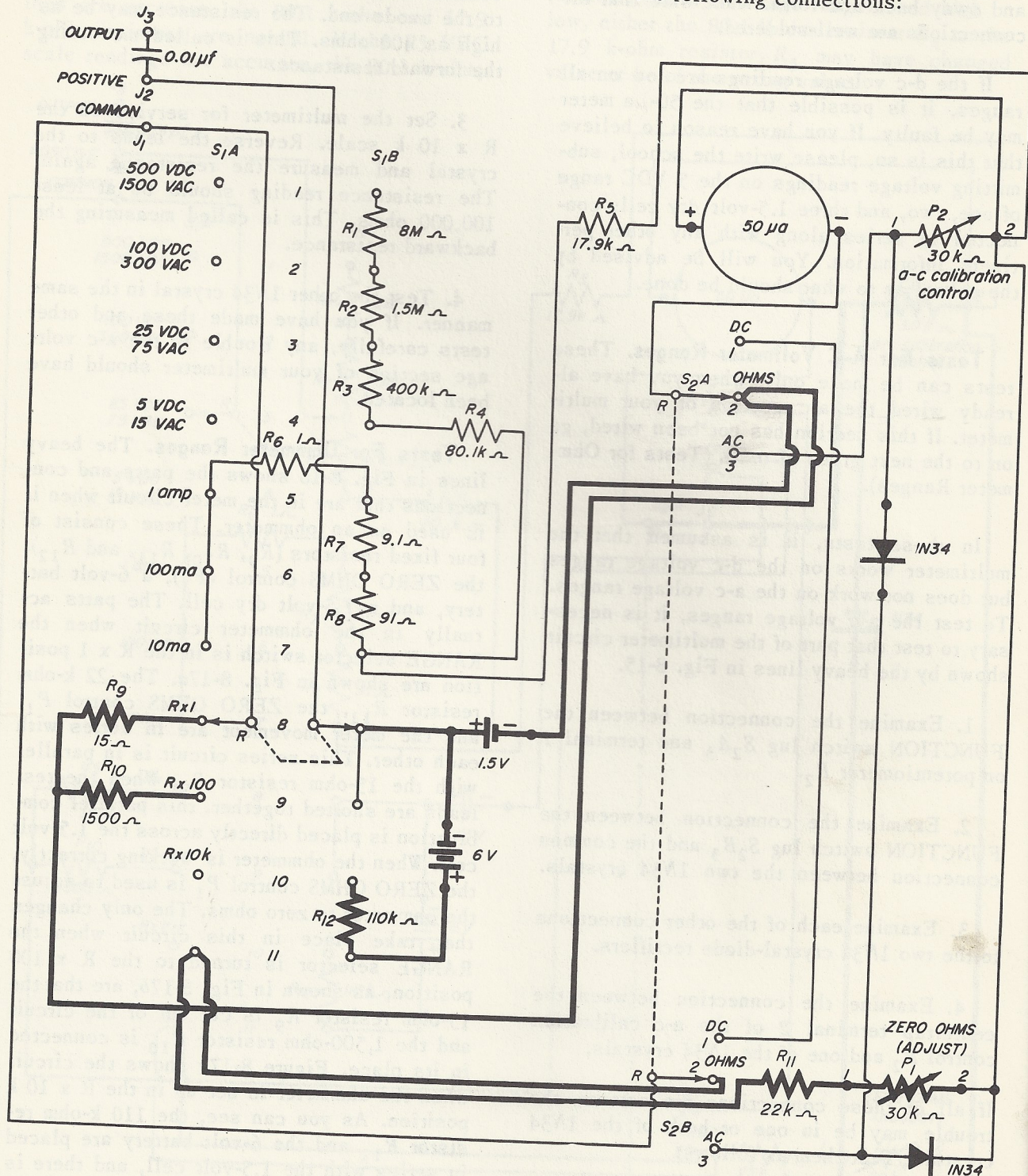
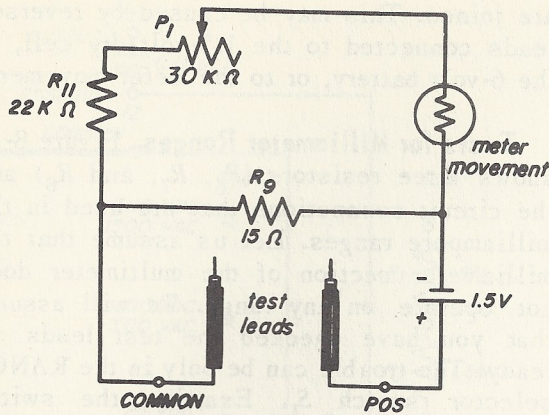
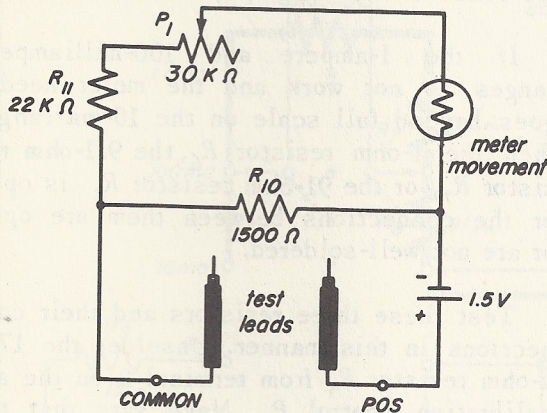


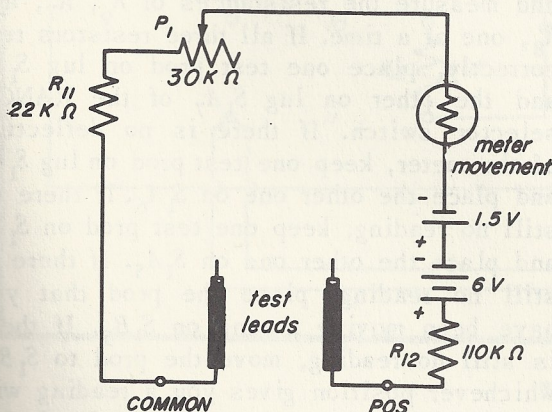
Fig. 8-16



Ohmmeter circuit in $R \times 1$ position.
(a)



Ohmmeter circuit in $R \times 100$ position.
(b)



Ohmmeter circuit in $R \times 10 K$ position
(c)

Fig. 8-17

1. The connection between lug S_1B_8 of the RANGE selector switch and the positive lug of the 1.5-volt battery clip

2. The connection between the negative lug of the 1.5-volt battery clip to lug S_2A_2 on the FUNCTION switch

3. The connections of the 22 k-ohm resistor R_{11} to lug S_2B_2 of the FUNCTION switch and to terminal 1 of the 30 k-ohm ZERO OHMS control P_1

4. The connection between terminal 2 of the ZERO OHMS control and terminal 2 of the a-c calibration control P_2

If all of these connections are in good order, it would appear that either the 22 k-ohm resistor R_{11} or the 30 k-ohm ZERO OHMS control P_1 is open. To check these:

Step 1. Remove the positive test lead from its pin jack on the meter panel and connect the negative test lead between the + and COMMON pin jacks, as you did when you checked the test leads.

Step 2. Moisten the forefinger of each hand and place one finger of each hand on each lead of the 22 k-ohm resistor.

If there is a deflection of the meter needle, you may be sure that R_{11} is defective. If there is still no deflection, test the ZERO OHMS control in the same manner — place one moistened finger on terminal 1 and the other on terminal 2. If there is a deflection of the meter needle, P_1 is defective. If there is no deflection, carefully resolder all of the connections that you have tested in the ohmmeter circuit.

Let us assume that the ohmmeter does not work on the $R \times 1$ position and that it does on each of the other two ohmmeter ranges. A possible defect is that the S_1B rotor blade does not make contact with the S_1B_8 contact clip on the RANGE selector switch.

Let us assume that the ohmmeter works on the $R \times 1$ and $R \times 10 K$ ranges and does not work on the $R \times 100$ range. A possible defect is in the connection between lugs S_1B_8 and S_1B_9 of the RANGE selector switch.

Let us assume that the meter works on the two lower ohmmeter ranges but does not work on the $R \times 10 K$ range. The trouble then

is in either the 110 K-ohm resistor R_{12} , the 6-volt battery, the connection between them, or the connection between the negative lug of the 6-volt battery clip and the positive lug of the 1.5-volt battery clip. The most probable trouble is that the battery is defective or that it is not making good contact with the terminals of its clip. You can test the battery by measuring its voltage on the 25 VDC range. The connections should be carefully inspected, and if the ohmmeter still does not work on the $R \times 10$ K range, the trouble must be in the 110 k-ohm resistor R_{12} .

Other Causes And Cures For Improper Ohmmeter Operation. We will now assume that the meter needle responds and indicates for all three ranges when the two test prods are joined. However, it is possible, due to incorrect wiring or a defective part, for one or more of the ranges to operate improperly. Some of the symptoms of improper operation on the $R \times 1$ and $R \times 100$ scales are:

1. Meter needle does not advance all the way to the zero-ohms position with the prods joined, no matter how the ZERO OHMS knob is adjusted. The trouble may be a weak 1.5-volt dry cell, the value of R_{11} may be too high, or a resistor of very low value may have been mistakenly used for the 15-ohm or 1,500-ohm resistor. On the $R \times 10$ K scale, either the 6-volt battery may be weak or R_{12} may be too high.
2. The meter needle forcefully goes beyond full scale when test prods are joined, and cannot be adjusted to zero with the ZERO OHMS control. The trouble may be incorrect wiring of both the 1.5-volt dry cell and 6-volt battery, or the values of R_{11} may be too low.
3. The ohmmeter does not accurately indicate resistance values within the normal combined tolerance of both the resistor being tested and the ohmmeter. The trouble may be that the 15-ohm resistor is not wired into the circuit or that the 15-ohm resistance has changed value.
4. Meter needle deflects toward the left instead of toward the right when the prods

are joined. This may be caused by reversed leads connected to the 1.5-volt dry cell, to the 6-volt battery, or to the meter movement.

Tests for Milliammeter Ranges. Figure 8-18 shows three resistors (R_6 , R_7 , and R_8) and the circuit connections that are used in the milliammeter ranges. Let us assume that the milliammeter section of the multimeter does not operate on any range. We will assume that you have checked the test leads already. The trouble can be only in the RANGE selector switch S_1 . Examine the switch carefully to make sure that the rotor blade on each deck is making contact with the 5th, 6th, and 7th lugs of each deck and that the connections to lug S_1B_7 are well-soldered.

If the 1-ampere and 100-milliamperere ranges do not work and the meter needle goes beyond full scale on the 10-ma range, then the 1-ohm resistor R_6 , the 9.1-ohm resistor R_7 , or the 91-ohm resistor R_8 is open or the connections between them are open or are not well-soldered.

Test these three resistors and their connections in this manner. Unsolder the 17.9 k-ohm resistor R_5 from terminal 2 on the a-c calibration control P_2 . Make sure that the free end of the resistor does not in any way touch any other lug, wire, or resistor. Set the ohmmeter for service on the $R \times 1$ scale and measure the resistances of R_6 , R_7 , and R_8 , one at a time. If all three resistors test correctly, place one test prod on lug S_1B_7 and the other on lug S_1A_7 of the RANGE selector switch. If there is no deflection of the meter, keep one test prod on lug S_1B_7 and place the other one on S_1A_6 . If there is still no reading, keep one test prod on S_1B_7 and place the other one on S_1A_5 . If there is still no reading, place the prod that you have been moving around on S_1B_5 . If there is still no reading, move the prod to S_1B_6 . Whichever position gives you a reading will show you that there is an open circuit between it and the last position from which you measured. If you have located the defect, resolder the free end of the 17.9 k-ohm resistor R_5 to terminal 2 of the a-c calibration control P_2 .

Checking For Causes of Inaccurate D-C Readings. In some cases, when your multi-

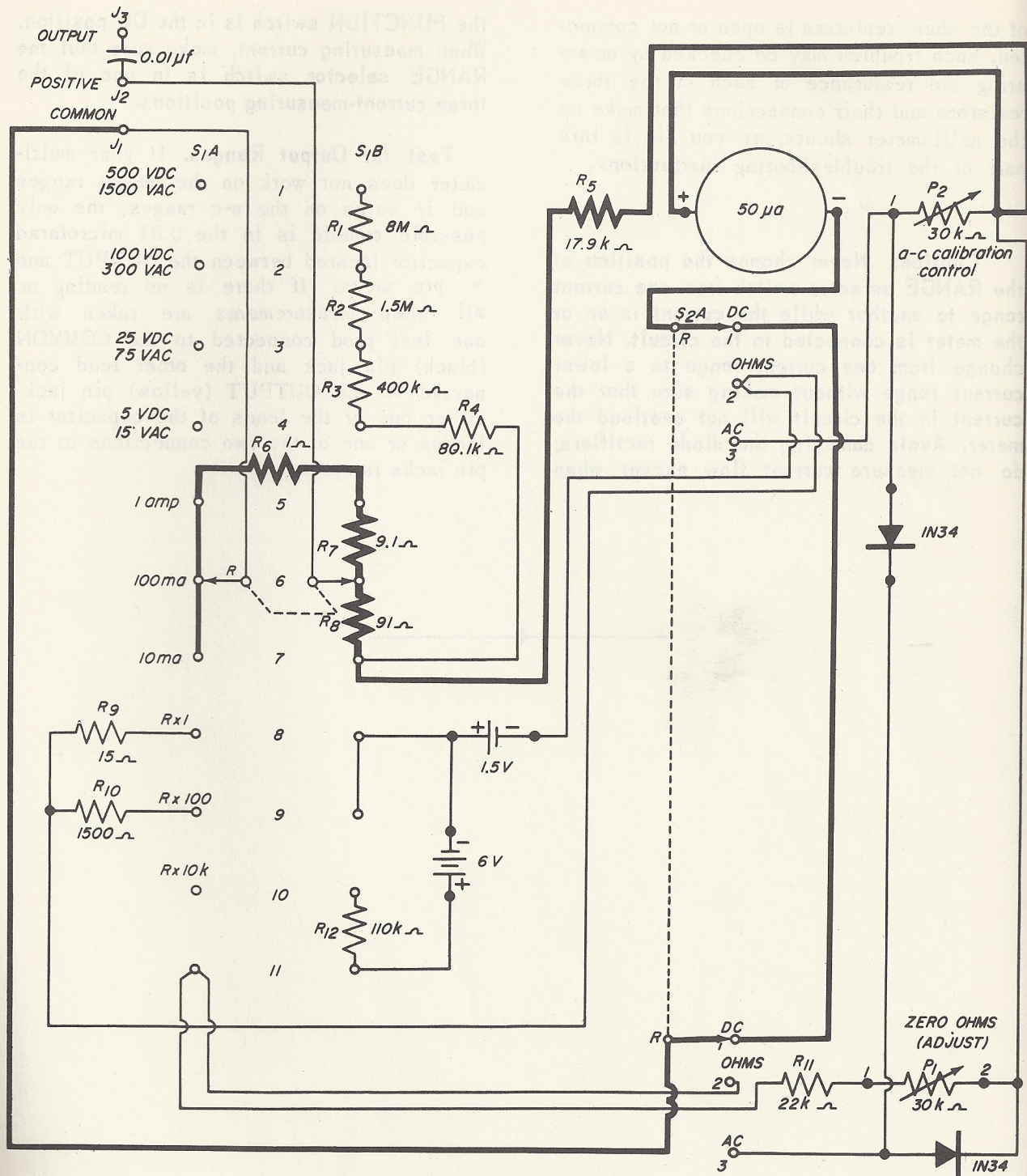


Fig. 8-18

meter is used to measure current, the current ranges may operate and still give you faulty readings on one or more ranges — readings that are too high or too low. When the position of the meter needle indicates an amount of current that is less than the actual current in the circuit, it will be because one or more of the shunt resistors is of too low a value.

If the position of the meter needle indicates a current that is more than the current actually flowing in the circuit, or if the needle goes beyond full scale or bangs against the needle bumper on the right side of the meter movement, then one of the shunt resistors is either too high in value, the circuit has high resistance connection, or one or more

of the shunt resistors is open or not connected. Such troubles may be checked by measuring the resistance of each of the three resistors and their connections that make up the millimeter shunts, as you did in this part of the troubleshooting instructions.

Caution: Never change the position of the RANGE selector switch from one current range to another while the current is on or the meter is connected to the circuit. Never change from one current range to a lower current range without making sure that the current in the circuit will not overload the meter. Avoid damaging the diode rectifiers; do not measure current flow except when

the FUNCTION switch is in the DC position. When measuring current, make sure that the RANGE selector switch is in one of the three current-measuring positions.

Test for Output Ranges. If your multi-meter does not work on the output ranges and it works on the a-c ranges, the only possible trouble is in the 0.01 microfarad capacitor located between the OUTPUT and + pin jacks. If there is no reading at all when measurements are taken with one test prod connected to the COMMON (black) pin jack and the other lead connected to the OUTPUT (yellow) pin jack, either one of the leads of the capacitor is broken or one of the two connections to the pin jacks is open.

